SUBCOURSE
EN5463

EDITION
B

US ARMY ENGINEER CENTER AND SCHOOL

QUARRY OPERATIONS I

Essayons

"LET US TRY"

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

A I P D

READINESS / PROFESSIONALISM THRU GROWTH

Quarry Operations I

Subcourse Number EN5463

Edition B

United States Army Engineer School
Fort Leonard Wood, MO 65473

Four Credit Hours
Edition Date: September 1992

Subcourse Overview

This subcourse will enable you to identify and state procedures to survey, investigate, evaluate, and select the best possible location for a quarry site and identify and state procedures to develop a layout and operations plan for a quarry or borrow pit operations. This subcourse is presented in two lessons, each lesson corresponding to a terminal objective.

There are no prerequisites for this subcourse.

This subcourse reflects current doctrine when this subcourse was prepared. In your own work, always refer to the latest publications.

The words "he", "him", "his", and "men", when used in this publication, represents the masculine and feminine genders unless otherwise stated.

TERMINAL LEARNING OBJECTIVES

ACTION: You will identify and state procedures to survey, investigate, evaluate and select the best possible location for a quarry site; identify and state procedures to develop a layout and operations plan for a quarry or borrow pit operations.

CONDITIONS: Given this subcourse.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70% on this subcourse examination.

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LESSON 1
SELECT A QUARRY SITE LOCATION

OVERVIEW

LESSON DESCRIPTION:

This lesson will teach you how to survey available sources of information, and to locate potential quarry sites. You will apply your knowledge of geology and terrain evaluation to evaluate potential sites, conduct field reconnaissance, and make a final site selection.

TERMINAL LEARNING OBJECTIVE:

ACTION:	Identify and state procedures to survey, investigate, evaluate, and select the best possible location for a quarry site.
CONDITION:	Given the material contained in this lesson.
STANDARD:	Correctly answer all questions in the practice exercise at the end of this lesson.
REFERENCES:	The material contained in this lesson was derived from TM 5-331-C and TM 5-332.

INTRODUCTION

Pits and quarries are selected on the basis of quality and quantity of material, location of the site, and factors affecting the ease of operation, environmental impact, and equipment and personnel requirements. Ideally, the best site is the one which can provide an adequate quantity of suitable material at the lowest cost in time, personnel, money, equipment and supplies.

Whenever possible, an existing site will be used. At existing sites the quality and quantity of material can be readily determined. Such sites are usually located near good haul roads with access roads already constructed. The amount of work required to remove overlaying waste material is greatly reduced and facilities and equipment may even be available. When possible, local operating personnel may be employed to reduce troop requirements.

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Learning Event 1:
IDENTIFY QUARRY TERMINOLOGY

You will need to know some basic terms which will be used frequently in this text.

Pits and *quarries* are sites which have been developed to provide select aggregates and other materials for construction use. Specifically, quarries are sites where open excavations have been made to remove rock for construction, usually by cutting or blasting. Pits are sites from which unconsolidated earth and rock particles are removed, usually without blasting. Pits and quarries are generally classified according to the type of material they contain and the methods used to excavate and process the material (Table 1). This subcourse is primarily concerned with quarries.

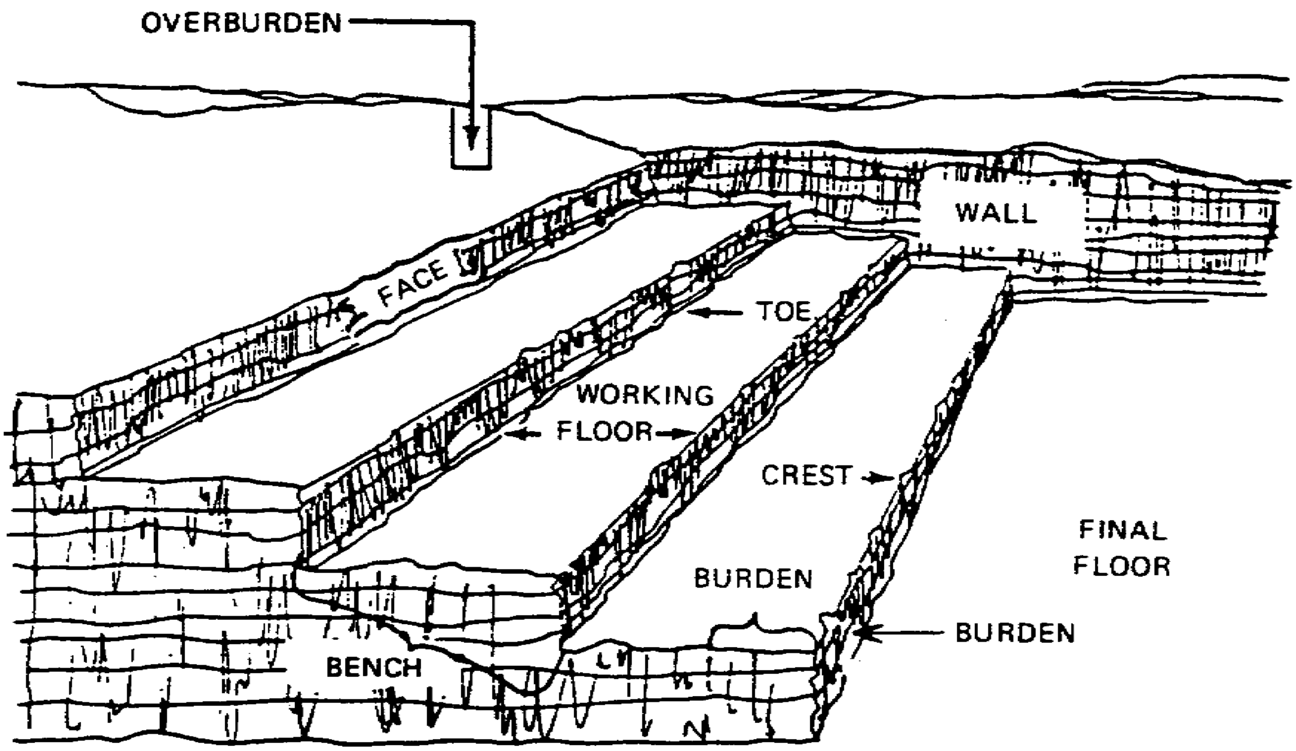
TABLE 1. CLASSIFICATION OF PITS AND QUARRIES

Type	Material	Primary Use	Operating Equipment
PIT:			
Borrow:	Select soil other than sand and gravel.	Fill for embankments and subgrades.	Scraper, dozer, rooter; power shovel, front loader, or dragline and dump trucks.
Sand or gravel:			
(Bank or hill)	Sand and gravel with clay.	Base courses, subbases, and fills.	Scrapers or pwer shovel, front loader, or hand tools and dump trucks.
(Alluvial)	Clean sand and gravel.	Aggregates for concrete and bituminous mixes and free-draining, non-frost susceptible fills.	Power shovel, front loader, dragline, or clamshell and dump trucks.
Miscellaneous: (Dumps)	Slag, mine tailings, cinders, etc.	Surfacing, fills, and aggregates.	Power shovel, front loader, or hand tools and dump trucks.
QUARRY:			
Hard rock:	Hard, tough rocks like granite, felsite, gabbro, diorite, basalt, quartzite, and some sandstones, limestones, and dolomites.	Aggregates for base courses, surfacing, concrete and bituminous mixes, free-draining fills and stone for rip-rap, embankments, and marine structures.	Rock drill, blasting materials and machine, power shovel, front loader, dump trucks, and crushing, screening (and washing) plant.
Medium rock:	Moderately hard, tough rocks like most sandstones, limestones, dolomites, and marbles.	Base courses and surfacing on roads and airfields and aggregates for some concrete and bituminous mixes.	Rock drill, blasting materials and machine, power shovel, front loader, dump trucks, and crushing, screening (and washing) plant.
Soft rock:	Cementaceous materials like limerock, coral, caliche, tuff, and laterite or weak rocks like disintegrated granite and some sandstones or conglomerates.	Fills and base courses and surfacing for roads and airfields.	Rooter, power shovel, front loader, and earthmoving equipment.

Overburden is the waste material which often overlies pit or quarry sites. This material must be removed before excavation of the construction materials lying below. Overburden refers to loose materials but locally it may include solid rock lying above the desired material. *Burden* is the construction material on the face of a quarry.

Figure 1 shows the names of various quarry features. The *floor* of the quarry is the inside bottom surface which marks the lower limit of excavation. Often quarries contain one or more *working floors* at various levels above the final quarry floor. A quarry *wall* is a more or less vertical surface which marks the lateral limit of excavation. The *face* of a quarry is a rock surface (usually vertical) from which rock is to be excavated. The top of the face is called the *crest* while the bottom is called the *toe*. A *bench* is a step-like mass of rock behind a face and below a working floor. Waste soil and rock materials which overlie the rock to be quarried are called *overburden*, while *waste* materials occurring within a deposit are called *spoil*. Notice that each bench has a face, floor, toe, and crest.

FIGURE 1. QUARRY TERMINOLOGY



A quarry may have one or more benches, depending upon how it has been developed. Compare the *single and multiple* bench quarries illustrated in Figure 2. Single bench quarries have only one working floor or operating level. Multiple bench quarries have two or more working floors arranged in step-like fashion.

There are three basic types of quarries: hillside, subsurface, and terrain. Figure 2 shows hillside and subsurface quarries.

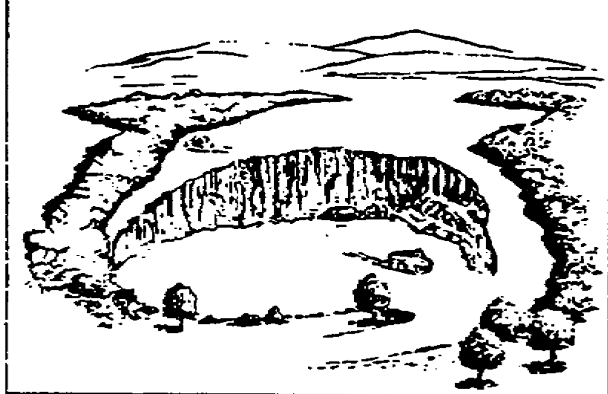
A *hillside quarry* is operated in rock which is part of the structural geology of a hill. Problems which may be encountered are overburden removal, grades, and multiple bench operation. Hillside quarries have the advantage of natural drainage and gravity flow of material from the quarry face.

A *subsurface quarry* is opened up below the level of the surrounding terrain. The requirements to remove material from below grade and dispose of it above grade are basic disadvantages. Also, subsurface quarries do not drain naturally and must be pumped periodically.

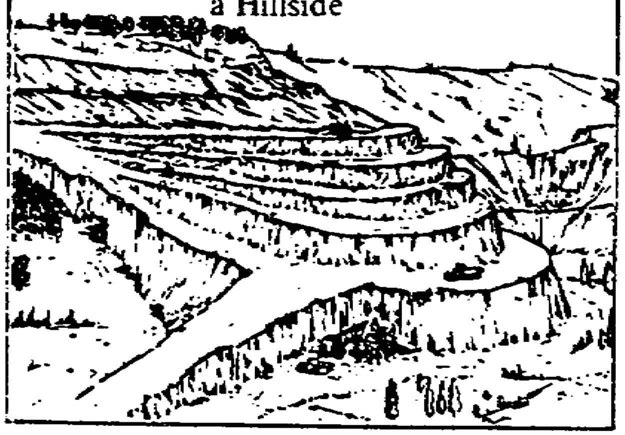
A *terrain quarry* is a temporary operation where the existing terrain is lowered and/or leveled. An example is an excavation needed to cut a roadway through a rock formation.

FIGURE 2. TYPES OF QUARRIES

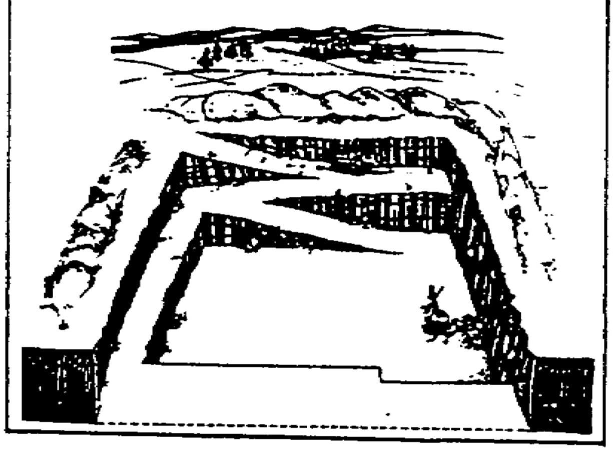
2.a Single Bench Quarry with Spiral Access



2.b. Multiple Bench Quarry on a Hillside



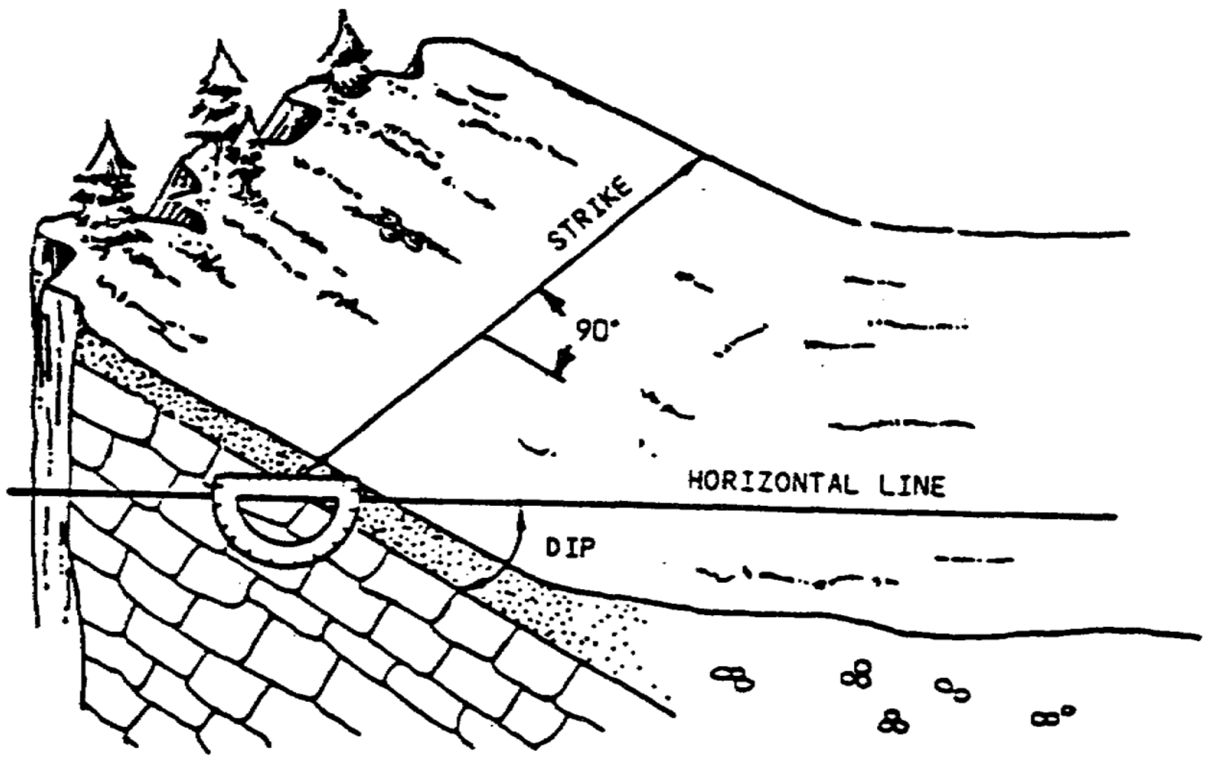
2.c. Multiple Bench, Subsurface Quarry



2.d. Subsurface Quarry with Switchback Access

The layout of the quarry depends to a great extent upon the direction of the strike and dip of the material to be quarried (Figure 3). *Strike* is the direction of the line of intersection of an inclined layer of rock with a horizontal plane. Strike is expressed as an azimuth or bearing. Dip is the maximum angular departure of an inclined bed from the horizontal. It is always measured at right angles to the line of strike. Dip is expressed in degrees.

FIGURE 3. MEASUREMENT OF STRIKE AND DIP



Learning Event 2
IDENTIFY ELEVEN FACTORS USED TO EVALUATE A QUARRY SITE

FACTORS AFFECTING SUITABILITY OF MATERIALS

Quality of Material. The intended use of the material is the determining factor in the quality required. In general, materials used for fills and subgrades do not have to meet the same specifications as those used for compacted rock surfacing, base courses, or pavements.

Seven properties of rocks are used to help select rock and aggregates for construction. Briefly, these rock properties are: toughness, hardness, durability, chemical stability, crushed shape, surface character, and density. Toughness, hardness and durability are commonly checked in the field with simple field tests.

Hardness is a rock's resistance to scratching or abrasion. This property is important in determining the suitability of aggregate for construction. Usually hardness is measured using Moh's scale shown in Table 2. The harder the material, the higher its number on the Moh scale. Any material will scratch another of equal or lesser hardness. In the field, hardness may be measured using the common expedients shown in Table 2. For example, if you are able to scratch a rock with a knife blade, the rock must have a hardness of 5.0 or less. A rock which can be scratched by a copper coin has a hardness of 3.0 or less.

TABLE 2. MOH'S SCALE OF HARDNESS

Mineral	*Hardness*
Diamond	10
Corundum	9
Topax or beryl	8
Quartz	7
Feldspar	6
Apatite	5
Fluorite	4
Calcite	3
Gypsum	2
Talc	1
Expedients	
Porcelain	7.0
Steel file	6.5
Window glass	5.5
Knife blade	5.0
Copper coin	3.0
Fingernail	2.0

Aggregates for general construction should have a hardness of 5 to 7. In other words, they should be difficult or impossible to scratch with a knife. Materials with a hardness greater than 7 should be avoided since they cause excessive wear to crushers, screens, and drilling equipment. Materials with a hardness less than 5 may be used if other sources of aggregate prove uneconomical.

The requirements as to toughness, durability, crushed shape, and other properties vary according to the type of construction. The shorter life spans required in the theater of operations permit a wider choice of materials than would otherwise be acceptable.

Remember that chemical stability has specific importance when considering aggregates for concrete. Several rock types contain impure forms of silica which react with alkalies in cement. This reaction forms a gel which absorbs water and expands to crack or disintegrate hardened concrete. These reactive

materials may be included in some gravel deposits as pebbles or as coatings on gravels. Potential alkali-aggregate reactions may be anticipated in the field by identifying the rock and comparing it to known reactive types or by investigating structures in which the aggregate has been used. Generally, light-colored or glassy volcanic rocks, chert, flints, and clayey rocks should be considered reactive unless proven otherwise.

An additional property of rock is gradation. This property is also important for evaluating rock as possible construction material. Gradation is the distribution and range of particle sizes which are present in, or can be obtained from, a deposit. The gradation of pit materials can be readily determined from simple tests. Quarry materials may be more difficult to evaluate. The upper limit of particle sizes available is normally controlled by the thickness of rock layers and the spacing of cracks or fractures in the rock. The amount of fine particles produced during rock crushing operations can be high variable. Generally, hard, tough rocks produce few fines while soft, weak rocks produce large quantities of fines, Weak sandstones and granites usually produce large amounts of sand-size material.

Types of Quarry Material. Natural sand and gravel are not always available and it is sometimes necessary to produce aggregate by quarrying and processing rock. Quarrying normally is done only where other materials of adequate quality and size cannot be obtained economically.

Many rock types suitable for construction exist throughout the world. The quality and durability of the rock type selected will therefore depend on local conditions. The following rock types are generally easy to quarry, durable, and resistant to weathering. When these are not available, it may be necessary to use softer rocks for base courses and surfacing on a temporary basis. The softer rocks will usually require little or no blasting.

- <u>Granite</u>. As a dimension stone, granite is fairly durable and has a texture and color desirable for polishing. As a construction material for base courses and aggregate, it is not as desirable as some of the more dense, fine-grained igneous rocks.
- <u>Felsite-Rhyolite</u>. This is durable and makes a good aggregate for base courses. It is not suitable for concrete aggregate.
- <u>Gabbro-Diorite</u>. Gabbro and diorite both have good strength and durability. The mineral crystals of both rocks are deeply intermeshed, making them very tough and excellent for construction aggregate.
- <u>Basalt</u>. The dense, massive variety of basalt is excellent for crushed rock for base course or bituminous aggregate. It is very strong and durable. Due to the high compressive strength of basalt, production may be more difficult than for other rocks.
- <u>Sandstone</u>. Few sedimentary rocks are desirable for construction due to their variable physical properties. However, sandstone is

generally durable. Because of the variable nature of the types of grains and cement, each deposit must be evaluated individually.

- Limestone. Limestone is widely used for road surfacing, in concrete, and for lime.
- Gneiss. Most varieties of gneiss have good strength and durability and make good road aggregates.
- Quartzite. Quartzite is both hard and durable. Due to these qualities, it is an excellent rock for construction, although it is often difficult to quarry.
- Marble. The texture and color of marble make it very desirable for dimension stone, and it can be used for base course or aggregate material.

QUALITY OF MATERIAL

Estimation of Quality. The quantity of material available at a site must be carefully estimated to include margin of safety. Unforeseen difficulties may arise which can reduce the estimated output. For example, excessive seepage may develop or material quality may decrease. All other factors being equal, it is better to select a site containing more material than is required, rather than one which just meets immediate requirements.

The quantity of quarry rock available is estimated by multiplying the average depth of the quarry face by the working area:

$$Q_t \text{ (volume)} = \text{depth x working area}$$

Then subtract waste rock and overburden to get a final estimate of volume. The following formula may be used:

$$Q_p = Q_t \, [1 - (W/100)]$$

where: Q_p = volume of product available
Q_t = total quantity of available material in deposit
W = percent of spoil or by-product expected after processing

Weight-Volume Relationships. Earth materials occupy a greater volume (loose volume) when they are loosened and removed from the ground. Bank rock or volume refers to earth materials naturally in place. The bulk volume of excavated material decreases when compacted. Where possible, the weight and volume relationships of materials should be measured during site investigation in order to accurately determine your requirements and potential yield. Where hasty estimates must be made, the values given in Table 3 may be used.

For example, you are managing a basalt quarry and need to estimate its yield. The average depth of the face is 30 feet. The quarry has a usable working area of 90,000 square yards. You know that about 10 percent of the rock is weathered and will be wasted. Determine how many cubic yards of *loosened* blast rock you can obtain.

First convert the depth of the face to yards:

$$\frac{30 \text{ feet}}{3 \text{ feet/yard}} = 10 \text{ yards.}$$

Then enter the values into the equations:

$$Q_t = \text{depth x working area} \qquad Q_p = Q_t[1 - (W/100)]$$

$$Q_t = 10 \text{ yds x } 90{,}000 \text{ sq yds}$$
$$= 900{,}000 \text{ CY of rock (bank)}$$
$$Q_p = 900{,}000 \text{ CY x } [1 - (10/100)]$$
$$= 900{,}000 \text{ CY x } (0.9)$$
$$= 810{,}000 \text{ CY of usable rock (bank).}$$

From Table 3, you find that one CY of average bank rock yields 1.7 CY of loose rock.

1.7 loose CY x 810,000 bank CY = 1,377,000 loose CY.

Therefore, your quarry should yield 1,377,000 loose CY of usable product.

TABLE 3. WEIGHT-VOLUME RELATIONSHIPS

Quantity	Average Value*	Normal Range of Values
SOIL:		
Bank weight:	1.5 T/CY	1.25 to 1.75 T/CY
	1.6 t/m^3	1.1 to 2.1 t/m^3
Loose volume:	1.2 CY/bank CY	1.1 to 1.3 CY/bank CY
	1.2 m^3/bank m^3	1.1 to 1.3 m^3/bank m^3
Compacted volume:	0.9 CY/bank CY	0.8 to 1.0 CY/bank CY
	0.9 m^3/bank m^3	0.8 to 1.0 m^3/bank m^3
ROCK:		
Bank weight:	2.25 T/CY	2.1 to 2.5 T/CY
	2.7 t/m^3	2.5 to 3.0 t/m^3
Loose volume:	1.7 CY/bank CY	1.5 to 1.8 CY/bank CY
	1.7 m^3/bank m^3	1.5 to 1.8 m^3/bank m^3
Compacted volume:	1.4 CY/bank CY	1.2 to 1.5 CY/bank CY
	1.4 m^3/bank m^3	1.2 to 1.5 m^3/bank m^3

*For example, 1 CY (1.5 T) of average soil will loosen during excavation to occupy 1.2 CY in a truck or stockpile and will compact to produce 0.9 CY of engineered fill in a road.

Lesson 1/Learning Event 2

FACTORS AFFECTING OPERATIONS

Ground and Surface Water Conditions. Test pits or auger borings should be used to determine the approximate amount of ground water seepage to be expected and to locate the water table. Many existing quarries contain standing water from seepage or rainfall which can often be drained with pumping equipment. Estimate the feasibility of removing water by installing a pump and gaging the rate of fall of the water surface. It is essential that most borrow pits be worked dry because it is difficult to move and compact borrow material when it contains excessive moisture. Gravel pits containing little or no clay can be worked wet if proper equipment is available. Quarries are worked dry unless it is impossible or impractical, as in operations involving coral reefs. Extensive drainage projects, such as diverting a stream or draining a lake or swamp, should be considered only when an extended operation is planned or when no other sites are available.

Location and Accessibility. Choose a location as close as possible to the construction site and convenient to good routes of transportation. This allows more efficient hauling by decreasing the length of access roads. Quarry haulage is ordinarily done by trucks. However, for large operations in the communications zone, rail and water transportation are sometimes used. When large quantities are being shipped by rail, lay a siding into the pit or quarry to eliminate trucking from source to railroad.

Overburden. Clearing the vegetation and overburden from a site may be as extensive an operation as excavating the material itself. Try to choose a site which will provide quality material with a minimum of grubbing, clearing, and stripping. It is impractical to operate a site where the depth of overburden exceeds one-third the thickness of the usable material. Overburden should not exceed a depth of fifteen feet (about 5 meters). For some types of construction, the overburden may be useful as fill material, either in its original state or after improvement by mixing with sand or gravel.

Slopes. Sites at which gravity can aid in the removal of materials are prcferable to those at which materials must be moved uphill. Consider, too, the effects of topography on drainage, road construction and quarry access, and on the location of processing and support facilities.

Jointing and Weathering. Joints are of considerable engineering importance, especially in excavation operations. Joints oriented at right angles to the working face present the most unfavorable condition. Conversely, joints oriented about parallel to the working face greatly facilitate blasting operations and yield even, smooth breaks. Joints can serve as water channels. As such they can increase drainage and weathering problems. Weather material should not be used for aggregate. The spacing of joints can control the size of material removed and can affect drilling and blasting.

WARNING: Drill steels can break or bind and explosive gases can escape out of rock joints.

Utilities and Facilities. If usable, existing roads, buildings, excavations, hardstands, equipment, and utilities may significantly reduce site development and operational costs. Clean water is essential in daily operations for equipment use and maintenance. Large volumes of water are required to wash aggregate for concrete and bituminous uses. Electricity and communications are also required utilities.

Equipment and Personnel. The availability of engineer equipment and trained personnel is a major factor to be considered in site evaluation. You should make maximum use of operable equipment found in-place at existing sites. Consider the state of training and experience of available troops at all times. It may be necessary, in extensive operations, to institute special training programs to meet acceptable standards of safety, maintenance and production.

Security. Pit and quarry sites are particularly vulnerable to enemy operations. Any major item of equipment destroyed at the site may close down the entire operation and the projects it supports until a replacement is received. Consider also the problems of pilferage, vandalism, and accidental injury to trespassers, particularly children.

Environmental Factors. Environmental problems and restrictions must be carefully considered before a final decision is made on the suitability of any potential pit or quarry site. Pit and quarry operations produce large amounts of noise, dust, vibration, and traffic. These may adversely affect local personnel, installations, water supplies, or roads. Blasting may limit the use of the airspace over a site or endanger local structures. In some cases, the suitability of a site may be influenced by its impact on the local economy or by the cost of restoring the site to a natural condition after operations have ended.

Learning Event 3:
IDENTIFY THE SEVEN SOURCES OF INFORMATION FOR SELECTING A QUARRY SITE

INTRODUCTION

Use three steps to find and evaluate potential quarry sites, then make the final selection. First, do a site reconnaissance survey. This is a research task to collect published and filed data, such as maps, reports, and aerial photographs. Second, do a field reconnaissance of those potential sites which are evaluated as high priorities. Finally, make a final site selection based on all available information.

SITE SELECTION

The first step you will take in site selection is the collection and study of all available information relative to potential pit or quarry locations. A thorough reconnaissance survey saves time by limiting the areas to be investigated to those having definite possibilities. Personnel trained in terrain analysis, soils analysis, or related fields should be used as aids to locate potential sites. You should use as many sources of data as possible to develop a reconnaissance plan to locate the best source of construction material. The amount of planning for reconnaissance for pit and quarry sites varies according to time limitations dictated by tactical considerations. Your reconnaissance survey will provide the plans necessary for any required field reconnaissance.

Sources of Information

The following seven sources of information may be used in a reconnaissance survey. You should use as many of these sources as possible to qualify potential pit and quarry sites.

Geologic Maps. These maps are excellent aids in finding pit and quarry locations. They provide information on existing pits, quarries, and mines and on the distribution and structure of subsurface geologic formations. Detailed geologic studies are not available for all parts of the world. Also, not all studies provide complete information on all categories of material. For these reasons, you may have to depend more on available topographic maps, soil maps, and aerial photography. The United States Geological Survey (USGS) publishes geologic maps and reports for the United States and some foreign areas. Many states and Foreign nations have similar geological survey agencies.

Topographic Maps. These maps show existing pit, quarry, mine locations and streams, transportation routes, cliffs, and other terrain features. The information available depends on the age, scale, and contour interval of the maps. Close inspection of topographic features, such as slopes and drainage

patterns, can provide valuable clues as to the relative nature of rocks, degree of weathering, soils, and drainage. When used with other sources of information, interpretations can often be made that could not be made from any single source.

Soils Maps. These maps are best suited for the location of potential pit sites. They present information on the distribution of soil units which are classified by thickness, texture, engineering properties, or other characteristics. They often provide data which reflect local drainage, ground water, or geologic conditions. It is best to use soil data with available geologic information to help clarify the details of subsurface conditions. Soil maps and reports are available through the Soil Conservation Service of the United States Department of Agriculture and from similar agencies in many foreign nations.

Aerial Photographs. You may request aerial photographs to supplement incomplete or dated maps or to substitute where maps are unavailable. Current aerial photos present an up-to-date picture of the land. Vegetation, roads, streams, rock outcroppings, excavations, and many other features can be clearly identified. An experienced interpreter can determine much information on rock types, soil, drainage, and ground water conditions from aerial photos alone. But the photos are most reliable when used with other sources of information or with ground investigation. Often aerial photos will be the only source of information available in the field.

Generally, an aerial photo shows dark tones where there is a high moisture content in the soils and/or heavy vegetative ground cover. Very dark tones may be dense forests or ponded water bodies. High topographic position and barren ground shows as light tones. A mottled tone is typically associated with limestone formations. A conspicuous banded pattern is a key to identifying exposed, interbedded limestone and shale. Limestone shows as a light tone while shale shows as dark.

Intelligence Reports. Strategic and tactical intelligence reports can be useful sources of information. Intelligence reports published by the Defense Intelligence Agency and the Central Intelligence Agency include information on soil types, rock formations. and existing pits, quarries, and mines. These are important sources for long-range planning. Strategic engineer analyses prepared by the Office, Chief of Engineers, and the engineer section of specified unit commands are also good sources.

Tactical intelligence reports compiled at all command levels are excellent sources of information on terrain and potential pit or quarry sites. After-action reports from units in the field, especially engineer units, may also identify potential sources of construction material.

Local Inhabitants. Residents may provide much useful data on local geology and engineering problems. Surveyors, contractors, engineers, farmers,

teachers, and local government officials are particularly useful. Residents are a quick source of information on local rock and soil types and on locations of readily available rock and soil exposures.

Miscellaneous Records. The records of drilling, mining, petroleum, and engineering companies may provide geologic and engineering data for many areas which have been explored or developed commercially.

Learning Event 4
DESCRIBE PRIORITIES WHEN CONDUCTING A FIELD RECONNAISSANCE

The pit or quarry sites located from your survey should be field checked. You must first establish priorities for such further investigations which will provide the data necessary for final site selection. You will determine the scope and nature of any required subsurface exploration. Investigation priorities are classified as known sites, probable sites, and possible sites.

KNOWN SITES

Known sites are those sites currently or previously used as pits or quarries. They are close enough to the construction site to warrant further investigation.

PROBABLE SITES

Probable sites are those that your survey found to contain desirable construction materials.

POSSIBLE SITES

Possible sites are those sites for which your survey indicated a possibility that construction materials exist. Information on these sites may have been obtained from visual or aerial photographic coverage and must be confirmed by individual investigation.

Subsurface investigation should be minimized by a thorough survey. Where necessary, a number of exploration methods are available for use. Geologic mapping, probings, wash borings, auger drilling, drive sampling, pneumatic drilling, and test pits and trenches are the more common methods. Of these, test pits and trenches are the most reliable and widely used. Core drilling and geophysical measurements are two other methods which are not normally available to field troops.

FINAL SITE SELECTION

Final selection of a pit or quarry site is made after all reconnaissance and exploration data has been collected, analyzed, and evaluated. To determine the most suitable site, the quality and quantity requirements must first be met. If more than one site satisfies these requirements, your ultimate choice must be based on location, equipment and personnel required, ease of operation, and other factors. The weight you assign any given factor in your evaluation will depend on your particular situation. For example, security may be a major consideration in a forward area, but a relatively minor one in the communications zone. For long term operations, you should weigh those

factors which most influence production costs, such as location, rock quality, slopes, and ground water conditions. If time or development costs are more critical, you should attach more importance to such factors as overburden, access, and existing facilities. Choose the site which best meets your mission requirements.

Lesson I
Practice Exercise

PRACTICE EXERCISE FOR LESSON 1

Instructions

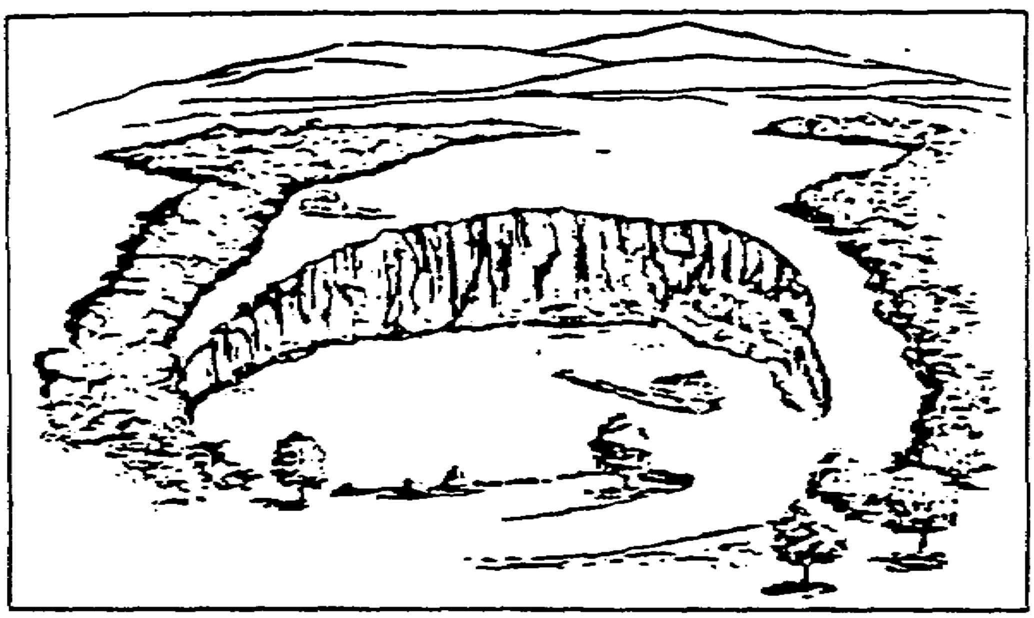
Check your understanding of Lesson 1 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

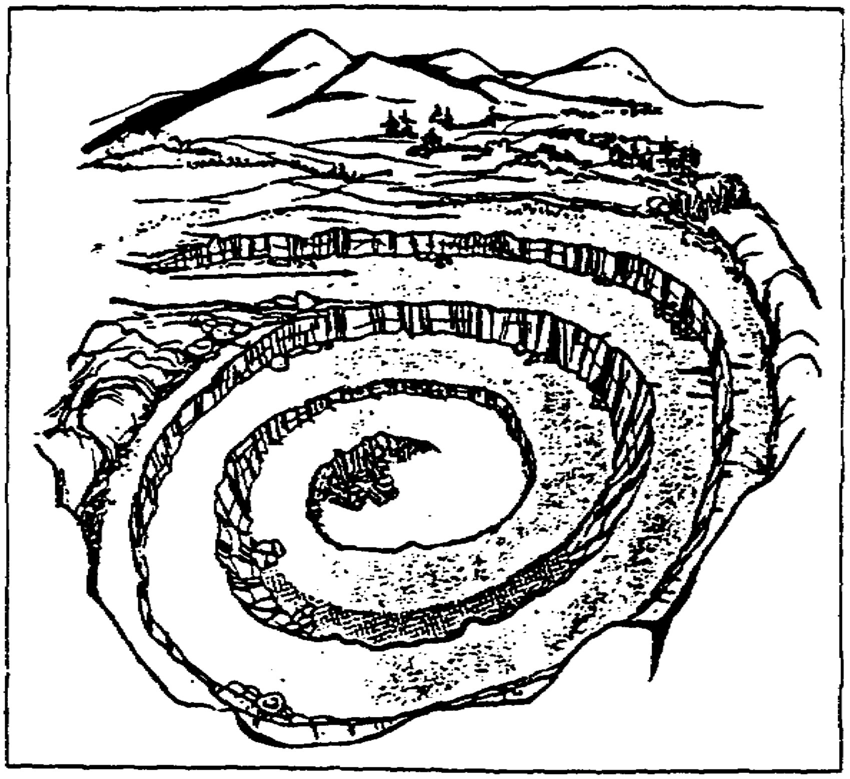
1. Quarries are distinguished from pits, primarily by their use of ______________________________ ________________________ to remove material.

2. Overburden is the ___________________________________ material which often overlies pit or quarry sites.

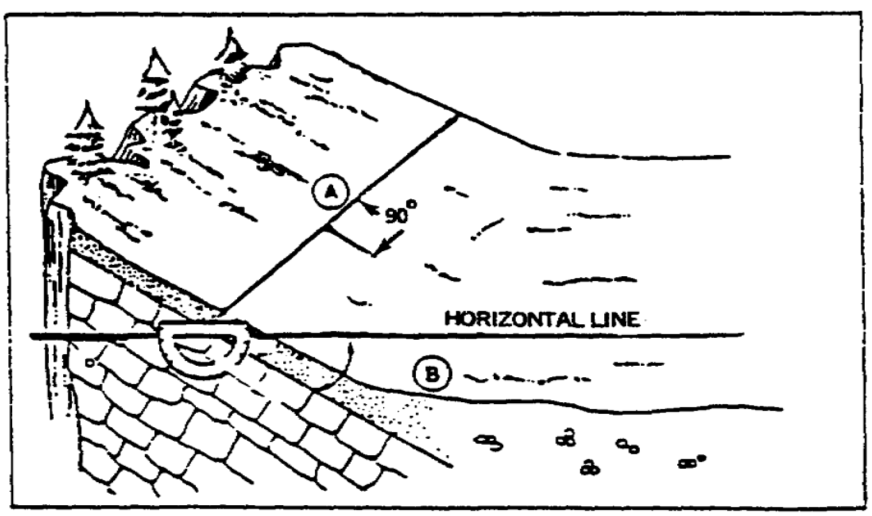
3. How many operating benches does this quarry have? ________________________
   What type of access does this quarry have? _____________________



4. This is a ________________________ quarry. (Choose one: hillside, subsurface, or terrain.) The ramp is a _______________________ access. (Choose one: spiral or switchback.)



5. A. indicates the direction of the line of intersection of the rock layer with the horizontal plane. A. is called the ______________________________.
B. is the maximum angular departure of the inclined rock bed from the horizontal. B. is called the ___________________________.



6. You use a simple field test to check the hardness of some potential quarry material. You are unable to scratch the rock's surface with a copper coin, but can scratch it with a knife blade. According to Moh's scale of hardness, how would you rate this material?____________________
Is this material suitable as an aggregate for general construction? ____________________

7. You are considering a possible quarry site. A critical factor for this quarry operation is quantity of material. Estimate the yield from this potential site (expressed in loose cubic yards) from the following information:
    - average depth of face is 24 feet
    - usable quarry working area is 110,000 square yards
    - about 12 percent of the rock is weathered

8. One of the potential quarry sites you are considering has the following characteristics:
    - the site is undeveloped
    - usable material is about 30 feet in depth
    - overburden is about 15 feet in depth

    Is this a likely quarry site? Why or why not? ____
    ____

9. You must find a quarry site for a construction operation. What three steps will you use to find, evaluate, and select a site?
    ____
    ____
    ____

10. Aerial photographs are very useful for ___________________ information. They are used most reliably, however, when ____________________________________.

11. You have conducted a site reconnaissance survey to find potential quarry sites. How will you classify these potential sites into priorities for further field reconnaissance?
    ____
    ____

12. There are a number of site evaluation factors which you must consider. The importance you place on each of these factors depends upon the particular situation. In a forward, theater of operations area, you will probably make ___________________________ an important consideration. A quarry planned for long-term operation in a civilian, residential area will probably make ________________________________ factors an important consideration.

Lesson 1/Practice Exercise Answers

Lesson
ANSWER SHEET FOR PRACTICE EXERCISE

Learning Event

1. blasting — 1

2. waste — 1

3. one; spiral — 1

4. subsurface; spiral — 1

5. strike; dip — 2

6. about 5; yes (Aggregates for general construction should have a hardness of 5 to 7.) — 2

7. 1,316,480 loose cubic yards — 2

$$\frac{24 \text{ feet}}{3 \text{ feet/yard}} = 8 \text{ yds}$$

Q_t = 8 yards x 110,00 square yards
= 880,000 cubic yards of rock (bank).
Q_p = 880,000 cubic yards x [1 - (12/100)]
= 880,000 cubic yards x (0.88)
= 774,400 cubic yards of usable rock (bank)

Check Table 3 and find that one cubic yard of average bank rock yields 1.7 cubic yards of loose rock.

1.7 loose cubic yds x 774,400 bank cubic yds = 1,316,480 loose cubic yards

8. no; the depth of overburden exceeds one-third the thickness of the usable material — 2

9. site reconnaissance survey, field reconnaissance, and final site selection — 3

10. current; used with other sources of information or with ground investigation — 3

11. known sites, probable sites, and possible sites — 4

12. security; environmental — 2 & 4

LESSON 2
DEVELOP A LAYOUT AND OPERATIONS PLAN FOR A QUARRY

OVERVIEW

LESSON DESCRIPTION:

This lesson will teach you to identify mission requirements and develop site layout and operations plan for a quarry or rock pit operations. The site layout plan establishes the location and arrangement of the quarry and its supporting facilities. The operations plan specifies the method and procedures to be used in developing and operating the complex. Usually, both plans must be considered simultaneously to assure the efficient, orderly development of the site.

TERMINAL LEARNING OBJECTIVES:

ACTION: Identify and state procedures to develop a layout and operations plan for a quarry or borrow pit operation.

CONDITION: Given the material contained in this lesson.

STANDARD: Correctly answer all questions in the practice exercise at the end of this lesson.

REFERENCES: The material contained in this lesson was derived from TM 5-331-C and TM 5-332.

INTRODUCTION

The development of a quarrying site consists of preliminary and continuing work to achieve the desired layout. This section covers the initial stages of development which include all the steps leading up to the establishment of a bench at the height planned and the completed installation of the screening and crushing plant. The diagram in Figure 4 illustrates the extensive array of equipment and personnel committed to a quarry and rock crushing project.

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FIGURE 4. KEY ELEMENTS OF A TYPICAL MEDIUM TO LARGE SCALE QUARRYING AND ROCK CRUSHING COMPLEX

QUARRY OFFICE

Responsible for overall control and administration of site activities.

ROCK PROCESSING OPERATION

Involves crushing, screening, washing, stockpiling, and issuing rock products.

Crushing unit(s)
Screening unit(s)
Washing unit(s)
Pump(s)
Generators
Conveyors
Bins
Front loaders
Floodlights
(Power shovels)
(Bulldozers)

EQUIPMENT MAINTENANCE OPERATION

Involves maintenance and repair of all plant equipment and all other on-site equipment.

Welding shop
Tire repair point
Shop vans
Parts vans
Contact truck(s)
Floodlights
Generator

STRIPPING OPERATION

Involves grubbing, clearing, stripping, and spoiling of all overburden materials.

Bulldozers
(Scrapers)
(Dragline)
(Power shovel or front loader with dump trucks)

QUARRYING OPERATION

Involves drilling, blasting, loading, and hauling rock.

Rock drills
Air compressors
Blasting materials
Power shovels
(Front loaders)
(Bulldozers)
Dump trucks
(Sump pump)

ROAD MAINTENANCE OPERATION

Involves daily routine maintenance to roads and traffic areas.

Grader(s)
Water distributor
(Bulldozer)

Learning Event 1
IDENTIFY MISSION REQUIREMENTS

Identify and analyze any requirements which are provided by the mission itself. Consider these factors:

- Site location
- Quantity of product
- Processing requirements
- Time frame involved
- Support available

You have probably considered most or all of these requirements during the site evaluation discussed in Lesson 1. Analyze these requirements now in terms of their effects on site layout.

Learning Event 2
DESCRIBE SITE LAYOUT PLAN

Quarry site layout consists of preplanning the location, dimensions, and arrangement of the quarry and its supporting roads and facilities. Its objectives are to assure that:

- Adequate space is provided for all future activities
- The flow of materials will be as safe and efficient as possible
- Personnel and special equipment requirements are recognized and provided for.

Special consideration must be given to the characteristics and limitations of the equipment to be used at the site. The quarry complex is comprised of two basic operational units. The plant operation is that area where quarry material is processed. The material is crushed, screened, and washed here. The quarry operation is where the actual removal of rock and other usable material takes place.

Military quarries are usually open-pit operations which involve vertical faces from 8 to 40 feet (2.4 to 12 meters) high. Depending on site conditions, production requirements, and available resources, these quarries may be developed by the single or multiple bench method.

A single bench quarry is relatively easy to plan, develop, and supervise because it has only one working floor. It also requires less equipment and personnel to operate than a multiple bench quarry. For these reasons, most military quarries are single bench. Unless such quarries are large enough to accommodate several blasting and loading points, they tend to be relatively inefficient where high rates of production are needed.

Multiple bench quarries require careful planning, complex road networks, closer supervision, and more operating personnel and equipment. However, each level can operate more or less independently in multiple bench quarries. This provides greater continuity of operation and more efficient rock production than single bench types provide.

DIRECTION OF WORK

The first step in layout planning is to determine the best direction in which to work the quarry. The working face(s) of the quarry should be oriented to minimize the undesirable influences of the rock mass to be excavated.

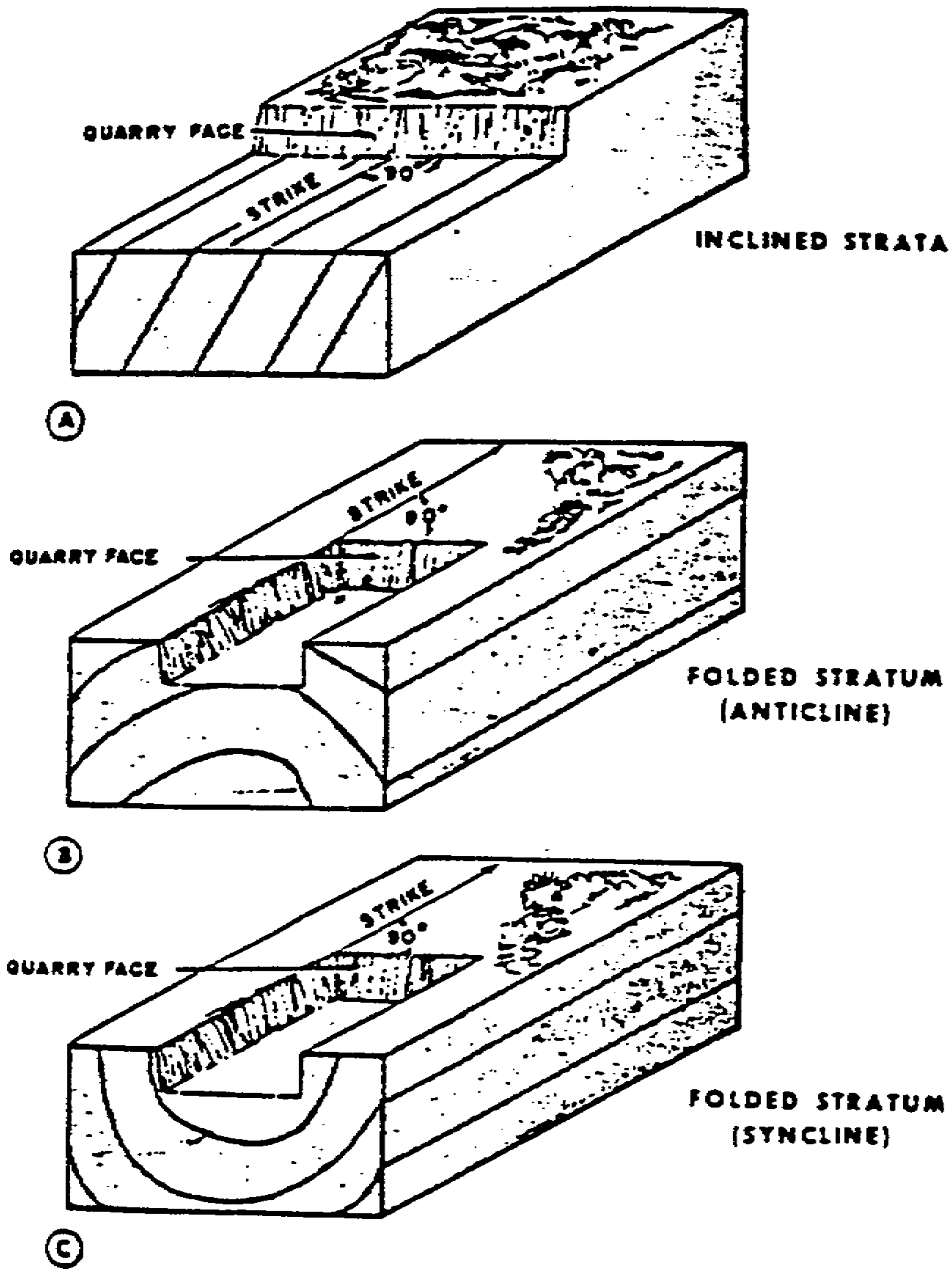
Massive or Horizontal Rocks. In unfractured, massive, or horizontally layered rocks, internal structure has no impact on the direction of work. Other criteria, such as site topography, access, and overburden variations, may be used to determine the best orientation of the quarry, face.

Slightly Inclined Rocks. Where the rock mass contains parallel layers or fracture surfaces which are slightly inclined, the quarry face should be oriented parallel to the strike of the rock. In this way work may proceed up the dip of the sloping rock surfaces. The bedding or fracture planes can thus be used to help maintain an even, well-drained quarry floor.

Steeply Inclined or Folded Rocks. Where rocks are folded or contain steeply-inclined layers or fractures, the quarry face should be oriented at right angles to the strike of the rock structure. This eases the problem of maintaining a vertical face and reduces drilling and safety hazards. If the quarry face is oriented parallel to the strike of the rock (with rock layers or fractures inclined toward or away from the face), problems with toes, overhangs, rock-falls, and rock sides will extend along the entire width of the working area along the face (Figure 5).

Vertical Rocks. Where rock layers are essentially vertical, the quarry face may be worked either parallel to strike (to aid in maintaining an even face) or perpendicular to strike (to aid in maintaining even quarry walls). Blasting is more efficient when the face is parallel to strike.

FIGURE 5. DETERMINING THE DIRECTION OF THE QUARRY FACE



QUARRY DIMENSIONS

Bench Height. Equipment limitations and geologic conditions most influence the decision as to what bench heights are best suited to your quarry operation.

The characteristics of common military rock drills are given in Table 4. Most quarrying operations employ track-mounted drills equipped with sectional drill steels. These are 10 or 12 feet (3.0 or 3.7 meters) long and can be coupled together as required. Drill holes are usually subdrilled 2 to 3 feet (0.6 to 0.9 meter) below the quarry floor. This assures complete rock fragmentation between holes during blasting. For convenience, benches are often planned to accommodate some unit number of drill steels (usually 2 to 4). Since drill efficiency decreases about 20 percent for each additional length of steel used, lower benches are usually preferred when drilling is difficult. Relatively lower benches are also preferred where rockfall and rockslide hazards exist along the face and where front loaders are used in loading out blastrock.

TABLE 4. MILITARY ROCK DRILL CHARACTERISTICS

Drill Type	Bit Diameter	Normal Drilling Depth	Maximum Drilling Depth
Hand-held	1 5/8 to 2 in 4.1 to 5.1 cm	6 to 8 ft 1.8 to 2.4 m	10 ft 3 m
Wagon-mounted	2 to 3 in 5.1 to 7.6 cm	10 to 20 ft 3 to 6 m	23 ft 7 m
Track-mounted	2 3/4 to 4 in 7 to 10.2 cm	20 to 40 ft 6 to 12 m	More than 50 ft More than 16 m

Where layers of undesirable material occur within a deposit, benches should be planned so that the undesirable and desirable materials may be excavated separately. This prevents contamination of the quarry product. Such surfaces reduce subdrilling requirements and aid in maintaining an even quarry floor.

Face Width. As a minimum, quarry faces should be wide enough to meet daily blast rock requirements and not narrower than the turning radius of the rock loading equipment. This radius normally ranges upward from 40 feet (12 meters). Faces wide enough to provide blast rock for at least several days of operation are preferred since weather conditions or other considerations may interfere with blasting schedules.

Final Dimensions. The final quarry floor is the ultimate bottom of the quarry. It is determined by the geology, rock requirements, and area restrictions. This ultimate bottom may be achieved in several lifts or working floors in the case of a multiple bench quarry. For example, you determine that the rock must be excavated to a depth of 60 feet (18 meters) over a given area to obtain the required volume of rock. You also determine that the optimum bench height is 20 feet (6 meters). Therefore, the quarry floor will be exposed at the third lift. Geologic factors which may limit the depth of a quarry include the depth of the water table and the thickness of usable material. It may be possible to work below the water table in some cases, but plans must be made to control the amount of water in the quarry throughout the operation.

Area restrictions as a limiting factor are particularly applicable to subsurface quarries. In planning the layout of a quarry, particularly a subsurface quarry, the minimum length of a uniformly sloping access road will be equal to the depth of a quarry divided by the grade limitation of the loaded hauling equipment. Ten percent is a good figure for trucks. For example, if trucks are used to haul from a quarry 60 feet (18 meters) deep, the approximate minimum length of the haul road required to leave the pit will be:

$$\frac{\text{60 feet}}{\text{0.10 grade}} = \text{600 feet (approximately 180 meters)}$$

After the levels of the quarry floor have been determined, the surface dimensions of the quarry are determined based on the total rock volume required. The relationship is simply:

$$\text{Total Bench (Surface) Area Required} = \frac{\text{total rock volume required}}{\text{average bench height}}$$

For example, a bench 30 feet (10 yards) high is used and the total volume of rock to be quarried is 1,500,000 cubic yards. The bench surface required is:

$$\frac{\text{1,500,000 cubic yards}}{\text{10 yards}} = \text{150,000 square yards}$$

If the quarry is to be worked as a hillside quarry, you could obtain the necessary area by adding the volume of each working level, as follows:

Top Level	10,000	square yards
30-foot Level..	40000	square yards
60-foot Level..	100,000	square yards

For a subsurface quarry, you could use a surface area of 150,000 square yards with one working level or 75,000 yards with two working levels and so on. When you determine the surface dimensions of a quarry, you should also consider:

- the optimum length and width for minimum overburden removal
- traffic patterns and access road requirements
- boundary limitations
- proximity of inhabited dwellings or structures subject to blast damage

Overburden

The location of overburden disposal is a primary consideration when planning overburden removal. This location is called a spoil area. Overburden should be disposed of in a place where it will not have to be handled a second time. It should be clear of all areas planned for future use. Normally, overburden will be piled to the right and/or left of the longitudinal axis of the quarry. On hillside sites, it will be piled on the downhill side, outside the pit area. For safety reasons, overburden should never be piled within 50 feet (16 meters) of the quarry rim. In planning overburden disposal, consider the relationship of spoil areas to drainage plans and the possibility of using the overburden as construction fill.

Haul and Access Roads

Roads to the rim of the quarry will follow the shortest and easiest route practicable. Grades will be limited to a maximum of 10 percent for truck operation. Curves should have sufficient radius to cause minimum delay in hauling. As a guide, roads should be designed for safe negotiation at not less than 20 miles per hour (32 kilometers per hour) by a loaded dump truck. Two-way roads to and from operational areas are usually adequate. However, one-way loop roads are essential within operational areas so that the routes of loaded and empty trucks do not cross. A straight ramp, spiral ramp, or switchbacks will be needed to maintain acceptable access from the boundary of the pit to the working face.

Drainage

Precipitation and ground water seepage must be kept drained away from the quarry face and other areas. The working floor of the quarry should slope away from the face to prevent water accumulation in the blasted rock and loading areas. A three percent slope is adequate. In a hillside quarry, water may be drained off naturally by gravity flow. In subsurface operation it will be necessary to provide a collection point where water can be accumulated for pumping. These collection points are called sumps. Sumps should be located away from traffic areas or any other area where they would interfere with efficient operation.

Equipment Positioning

Air Compressors. Most rock drills are powered by air compressors mounted on trailers, wheels, or skids. If necessary, these air compressors can be moved around with the drills they support. However, for deliberate operations of long duration, it is more desirable to permanently station the compressors.

Rock Crushers. The rock crushing, screening, and washing plant should be located close to the quarry face, but not close enough to be endangered by

quarry blasting. By locating the plant as close to the quarry as possible, you can make the maximum use of hauling units. This is important because the raw material from the quarry contains both product and by-product. The material hauled from the plant to the construction site contains only product size material. If the crusher can be located close enough to the face, dozers may be able to push blastrock directly to the crusher loading chute. Otherwise, both loading and hauling equipment will be needed. Bc sure not to locate the plant in the path of future excavation.

The actual plant site should be a secure area of stable ground large enough to accommodate the plant and related equipment, stockpiles of crushed rock, and loading operations. The terrain should be suitable in load-carrying ability to support heavy equipment with only minor earthworking improvements and sloping to provide good natural drainage. Proper utilization of a hillside or sloping location may permit the use of gravity as an aid in moving material from the face to the plant, from the plant to a storage area, or from a storage area to haul units. The site should be accessible to construction operations and, if aggregates are to be washed, to a source of water.

Generators. Most rock processing plants are powered by electricity. If power must be generated on-site, the generators should be located under shelter near, but upwind from, the plant. Power lines should be mounted on poles high enough to clear all traffic.

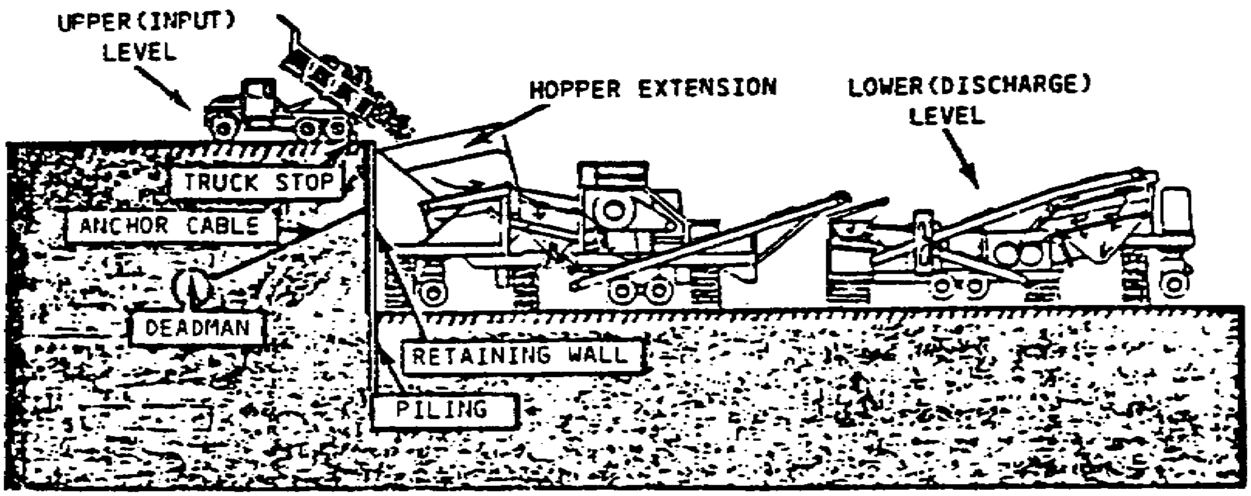
Materials Handling and Storage Facilities

Layout plans should include adequate materials handling devices to expedite the flow of material through the plant and eliminate double handling. Gravity flow through chutes will be used where possible to eliminate the need for loading and hauling units. Multiple levels are therefore preferred.

Headwalls and Loading Ramps. Normally use two levels for the crushing operation (Figure 6). Quarry run rock is dumped directly into the apron feeder or into a loading chute by trucks or dozers at the upper level. The rock is then processed through the plant on the lower level.

For operations of short duration, material may be fed into the apron feeder by means of a clamshell, dragline, or power shovel. These alternate methods involve double handling the material and are far less efficient. They also create more safety hazards in the plant area. If a suitable bench is not available, a compacted fill or crushed-rock loading ramp will have to be constructed in addition to a headwall.

FIGURE 6. CRUSHER SETUP WITH TWO WORKING LEVELS



Grizzlies and Scalping Screens. If you expect a problem with oversize material, a pre-screening grizzly should be built in the quarry. The grizzly removes oversize rocks before it is hauled to the plant. If undersize material is a problem, a scalping screen should be built to remove it. If the grizzly or scalping screen cannot be built in the quarry, it may be constructed over the apron feeder of the primary unit of the plant. In this instance, adequate space must be provided to stockpile the undesirable material until it can be removed for disposal or secondary breakage.

Surge Piles. You should have surge piles of material ready for use at each step in the rock processing operation. In this way all units may operate at full capacity and continue in operation despite interruptions in the normal flow of material. For example, a surge pile of quarry run material should be convenient to the apron feeder of the primary crusher so that a dozer or front loader can load the crusher when haul units are not on hand. Normally this surge pile should contain enough material to sustain operations for several days should inclement weather, maintenance or quarry blasting interrupt

hauling from the quarry. In some cases, surge piles will be planned to sustain operations much longer, as for an entire winter or monsoon season. Often, such piles are planned to allow for late arrival or early release of some elements of the operation.

Bins. When possible, you should store quality, product-size material in elevated or inclined storage bins rather than in open stockpiles. Bins prevent contamination of the material by wind-blown dust and trash and allow complete recovery of the product without double handling. Rock fed into the top of a bin from the crusher may be discharged into hauling units through a trap door in the bottom of the bin. If bins are not available, they may be constructed of wood or metal.

Stockpiles. If bins are not used, place product-size materials in open stockpiles. If more than one product is being produced, each product pile will be separated by distance or headwalls from all others to prevent contamination. Specially screened or washed products will be stored upwind from the plant to minimize contamination by windblown dust. Material from the plant may be placed on the stockpiles by conveyors, dozers, trucks, or some combination of these. When planning stockpile locations, be sure to allow adequate space for storage. Plan enough room on the front side of the piles to load out units without causing traffic congestion.

Other Facilities

Water Supply. Water may be required for washing aggregates. If there is no stream or lake nearby, drill a well and dig ponds for storage water. For a recirculating water system, two ponds are needed. One pond will be a reservoir and one a settling basin. Water from the reservoir is pumped to the washing unit, used, and then discharged into the settling basin. Dirt, fines, and organic material are allowed to settle out in this basin. Clean water from the settling basin is then allowed to overflow back into the reservoir. A similar arrangement may be required where stream flow is unreliable and a dam is used to create the needed reservoir. Even where permanent streams or lakes are used as reservoir, you should construct a settling basin to protect surface water supplies from contamination.

Maintenance Areas. Maintenance hardstands, work shelters, and repair parts storage facilities should be convenient to both the quarry and plant areas. They should be upwind from all major sources of dust. They should be located on the internal road net so that heavy plant equipment will not have to be taken out onto primary roads for repair.

Quarry Office. Provide a building or shelter along the access road to the plant. The plant officer will use this area to keep records on plant production, maintenance, and deliveries.

Explosive Storage Magazines. Quarry blasting materials should be stored in clean, dry well-ventilated, reasonably cool, bullet and fire resistant shelters. For convenience, the magazines should be readily accessible to the quarry. But a safe distance must be maintained between the explosives and any other installation which might be endangered. Blasting caps will never be stored in the same magazine with other explosives.

Lighting. If a quarry or plant is to be operated during the night, you should provide a pole-mounted lighting system. Commercial electricity or on-site generating equipment may be used for power. Normally, portable installations are used within the quarry while permanent lights are used in the plant area. Assure that all power lines are strung high enough to clear all traffic.

Miscellaneous. During site layout planning, consider requirements for latrines, POL storage, parking, communications, and site security.

Learning Event 3
DESCRIBE THE PLANT INSTALLATION CONSIDERATIONS

OPERATIONS PLANNING

After the layout of the quarrying site has been determined, prepare a detailed operations plan. This plan should specify the methods and procedures to be followed for the entire life span of the quarry. It should take into account the factors of required production, equipment available, site conditions, maintenance requirements, safety requirements, and troop availability and training.

You should start work on the installation of the crushing, screening, and washing plant as soon as possible after the site becomes accessible. Work can then progress simultaneously with the construction of access roads and opening of the quarry. The crushing operation is normally done on two levels (see Figure 6), requiring construction of a retaining wall.

SITE PREPARATION

Plant site preparation consists of the following basic steps:

Preliminary Earthwork. Initially, cut the lower level of the site to the proper grade and dimensions. A predetermined portion of the excavated material may be deposited above the planned headwall anchorage for later use in backfilling behind the retaining wall. Where necessary, earthwork may also include the excavation of water storage and settlement ponds.

Hardstands. Plant equipment should be stationed on stable hardstands which are capable of supporting the weight and vibration of the plant without settlement. Ideally, hardstands should be constructed of reinforced concrete, but this is seldom practical in the theater of operations. A primary crusher can be used to provide base course material for hardstands. This material should be carefully leveled and thoroughly compacted to provide adequate support.

Headwalls. You may begin work on the crusher headwall after completion of the earthwork on the lower level. Support for the headwall may be provided by driven piles. Holes may be drilled and piles or posts set in and concreted individually. Or the base of the wall may be entrenched and piles set in a continuous concrete footer.

STATIONING THE PLANT

Crushing and screening plants can be operated from their wheelbase for short periods. However, it is better on longer and more deliberate jobs to block

the plant with the tires clear of the ground. Twelve by twelve-inch timber cribbing or other suitable material may be used for this purpose. Before crushing operations begin, the plant should be leveled from end-to-end and side-to-side. Otherwise, material will be channeled along the low side or end of the plant and increase wear and tear on the equipment.

Hopper Extensions

If the material is to be dumped directly into the apron feeder of the primary crusher unit, extensions must be welded onto the hopper. These extensions should increase its width to approximately 1.25 times that of the truck beds.

Loading Chutes

A loading chute is used when a suitable bench greater than 18 feet (5.5 meters) in height is used. It is also used when you have a grizzly at the crusher site and a suitable size bench or loading ramp is to be constructed. For very high headwalls, the use of an inclined chute will allow equipment to operate at a greater distance from the edge of the wall. This reduces the earth pressures against the wall. Whenever chutes, bins, or hoppers are used to handle large rocks they should be kept one-third full so the impact of falling rocks is absorbed without damaging the structure or equipment.

Grizzlies and Scalping Screens

Grizzlies are essentially very coarse screens for sizing a quarry run rock before it reaches the crushing plant. They consist of a durable, rigid, rectangular frame with steel rails spaced at intervals determined by the crusher opening. As a guide, the optimum size material fed into a jaw crusher is 75 percent of the jaw dimensions. For a 20 x 36-inch jaw crusher, this would be 15 x 27 inches. Grizzlies may be constructed for use at the crusher site. They may also be used in connection with loading ramps or constructed on skids for use in the quarry. When the quarry run rock contains excessive fine-sized material, scalping screens may be needed. These are constructed like grizzlies, but use fine screens. In this case, the screen should be sloped in the direction toward which the select material is desired to be moved.

Learning Event 4
DESCRIBE MAINTENANCE CONSIDERATIONS

Quarrying and crushing operations involve a wide variety of equipment and severe operating conditions. You should provide an on-site maintenance facility whenever practicable to minimize equipment repair time and maintain production. In addition to normal repair and maintenance capabilities, this facility should also be equipped for heavy-duty welding to repair shovel tracks and dippers, rebuild crusher jaws and rolls, repair truck beds, and for numerous other repair jobs that occur frequently. Provision should also be made for repairing tires, resharpening drill bits, and reconditioning drill steels. On large sites, contact trucks should be used to provide routine maintenance services directly to the operating equipment.

Learning Event 5
DESCRIBE ACCESS ROAD CONSIDERATIONS

You should construct access roads to the vicinity of the quarry and plant. Normally the access roads, or portions of them, will also be the haul roads from the quarry to the crusher and from the crusher to the customer units. Careful consideration should be given to the types and amount of traffic to which the roads will be subjected. For example, the access road to a quarry using a two-cubic yard power shovel must be designed to carry a load in excess of 60 tons. Roads should be surfaced with crushed rock and drained to reduce maintenance requirements. To reduce wear and tear on tires, the road surfaces should be kept smooth by constant shaping with a grader and free from large pieces of quarry run rock. Water should be applied to control dust in dry weather.

Learning Event 6
DESCRIBE OVERBURDEN REMOVAL CONSIDERATIONS

Grubbing and Clearing

If the quarrying site is wooded, your first operation in preparing the site is the clearing of all timber and brush. Brush can usually be disposed of by burning, but larger timber should be moved clear of the site boundaries. Suitable timber should be stockpiled for possible future use in the construction of headwalls and loading ramps. All stumps and large boulders should be excavated and removed from the site.

Stripping

Stripping overburden is essentially an earthmoving function. Stripping should be undertaken using bulldozers, scrapers, draglines, power shovels, or front loaders with dump trucks.

Overburden Removal

Overburden removal need not be completed before quarrying begins. However, the rock should be exposed in several places throughout the quarry site to ascertain the structure and configuration of the rock. In this way you can select the best possible approach to establishing the face. After the best approach has been determined, you should concentrate overburden removal in the approach area to begin quarrying with the least delay. Once rock excavation begins, overburden removal operations may be reduced in intensity to keep pace with the day-to-day requirements for rock production.

Learning Event 7
DESCRIBE QUARRY DEVELOPMENT CONSIDERATIONS

PROFILE

You must determine the location of the initial quarry face. To do this, a plan and several cross-sections across the length and width of the site should be drawn. These should show the surface configuration and structure of the in-place rock. Elevations on these drawings should be referenced to a bench mark outside the actual quarry. After profiles of the rock surface have been plotted, the quarry floor or first working level is superimposed at a depth equal to the planned bench height. The intersection of the floor or access ramp with the existing grade is the point where excavation should begin. Initial and subsequent working floors should be selected carefully to assure that continued development of the site will proceed smoothly. Overburden removal, access construction, traffic patterns, and rock excavation plans must be coordinated.

Steeply-Sloping Sitse. On steeply -sloping hillside sites, excavation should normally begin at the uppermost working level. A second, lower working level may then be established as the upper working floor approaches its intended dimensions or has been excavated enough to provide sufficient working space for further operations. Additional working levels may be established in a similar manner.

Gently-Sloping Sites. Excavation should normally begin at the level of the final working floor when quarries are established on gently-sloping sites. As excavation progresses, a second, higher working floor should be established when the initial bench reaches its intended working height. Additional, higher working levels may be established in similar, step-like stages if required.

Subsurface Sites. Like steep hillside quarries, subsurface quarries should be excavated from the top down. When excavation of the first lift has proceeded adequately, a second, lower level may begin and so on. Excavation plans should include provisions for access ramps and drainage sumps.

Cut Design

Open-pit quarries are normally operated with vertical faces for ease in drilling and blasting the rock. Two types of initial cuts, toe cuts and ramp cuts, are used to establish the initial, vertical quarry face. In addition, full face cuts parallel to the strike of the rock may be needed during the initial development of a site.

Toe Cuts. Unless the rock in a hillside or terrain quarry has a vertical face, you will have to remove a toe of rock to begin quarrying. This will require the use of different types of holes, shown in Figures 7 and 8. The method shown in Figure 7 usually gives better control over rock fragmentation and displacement and is preferred. However, the method shown in Figure 8 involves fewer setups. All vertical, steeply-inclined, and lifter holes should be subdrilled from 1 to 3 feet (0.3 to 0.9 meters) below the final grade to assure that the rock between holes will be broken to the desired grade line.

FIGURE 7. TOE REMOVAL BY HORIZONTAL AND VERTICAL BLASTHOLES

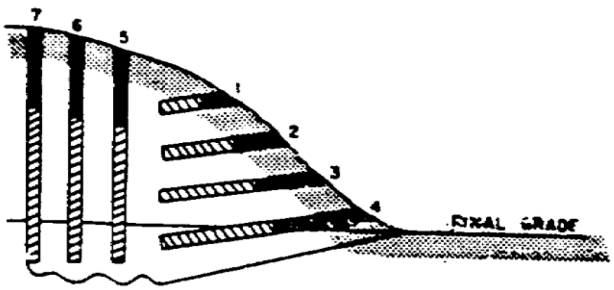
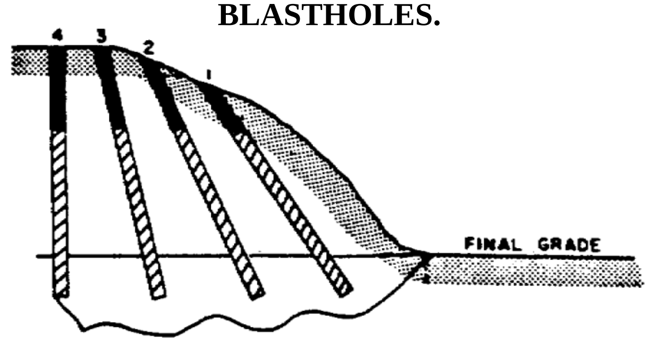
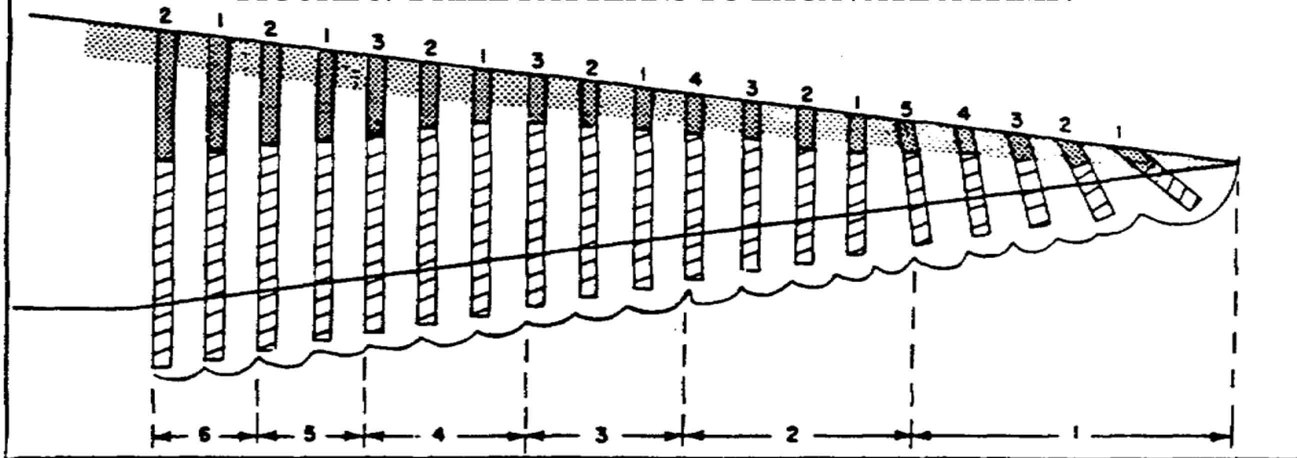


FIGURE 8. ESTABLISHING A VERTICAL FACE USING INCLINED AND VERTICAL BLASTHOLES.



Ramp Cuts. Figure 9 shows a suggested pattern for excavating a ramp down into a subsurface quarry. A vertical face is established in the first blast. Use of this method will allow the easiest possible loading of blasted rock. An alternate method is to establish a vertical face near the low end of the ramp using a V-cut or pyramid cut. Blasting may then proceed simultaneously up and down the ramp. The blasts at the lower end after the first V- or pyramid cut will normally be directed into the broken rock produced by previous blasts. Another method is to use a standard, full-depth vertical or steeply-inclined blast pattern to fragment the rock under the planned ramp to the level of the quarry floor. A power shovel or dozer may then construct its own ramp down into the pit. This allows for continuity in drilling and blasting operations. The resulting ramp car also be removed easily, should this be desired.

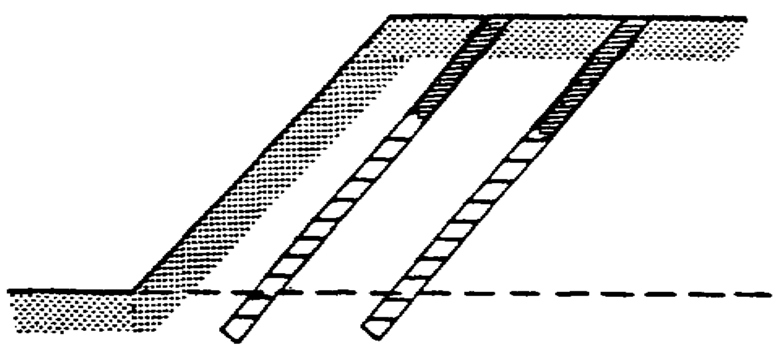
FIGURE 9. DRILL PATTERNS TO EXCAVATE A RAMP.



Cuts Parallel to Strike.

Dip Toward Face. When it becomes necessary to operate a face parallel to the strike with dip toward the face, satisfactory results may be obtained by drilling inclined holes parallel to the dip and working on the inclined face (Figure 10).

FIGURE 10. INCLINED BLASTHOLES (DIP PARALLEL TO FACE).



Dip Away From Face. This situation is more desirable than having to blast with the dip toward the face since rock slide hazards are less severe. Vertical blastholes may be employed as for a normal full face production blast. To eliminate overhang problems, one or more short, lightly-loaded blastholes should be spaced between the last row of primary blastholes.

Width of Initial Cuts. The total width of initial cut will be determined by working space requirements of loading and hauling equipment. For all cuts this width will be the same as the width desired at the initial face. In the normal method of loading out blastrock, i.e., with a crawler shovel or front loader, this width will range upwards from 40 feet (12 meters).

Charging Initial Cuts

The holes in initial cuts will normally be located with the same objective as in normal production blasting. This is to obtain good fragmentation with little displacement. However, in the case of cuts below grade (ramp, V-, and pyramid cuts), it may be advantageous to load heavy with the objective of removing as much material as possible from the cut with the blast. This practice may be limited by such factors as the proximity of personnel and structures to the area and the damage which may result from the shock and flyrock produced by blasting. A well designed blast results in good fragmentation, good displacement, and minimum violence.

Backfilling

All cuts described in the preceding paragraphs are intended to break the rock to a depth of from 1 to 3 feet (0.3 to 0.9 meter) below the final grade. Backfilling will be necessary to bring the surface up to a smooth, usable grade at the desired elevation. This must be accomplished to a certain extent with rock broken in the blast. However, a certain amount of usable fill with grading and compacting equipment may also be necessary to complete the job. Backfilling is not required when a suitable working floor can be developed by controlled blasting or by use of an existing bedding or fracture surface at the level of the quarry floor.

Excavating with Draglines

Draglines are best used to excavate loose materials below the track level of the machine. It is the most practical piece of military equipment for under water digging and is well adapted to submerged gravel pit operations. Typical dragline jobs are recovering sand, gravel, or coral from streambeds, lake bottoms, lagoons, and beaches. The primary use of draglines is to stockpile material for other loading equipment or to load hoppers.

Communications

Radio, wire, and special signalling devices for warning before blasting are essential to safe, efficient operations. Radios in the immediate vicinity should be turned off during loading and blasting of operations.

Lesson 2
Practice Exercise

PRACTICE EXERCISE FOR LESSON 2

Instructions

Check your understanding of Lesson 2 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing.

When you have completed the two lessons and your review, you can continue to the examination.

1. Your quarrying and rock crushing complex represents a great investment of time, personnel, money, and materials. Its development requires careful planning. Identify and explain two basic plans you must develop in order to effectively design a quarrying complex.
   a. ____________________
   ____
   b. ____________________
   ____

2. Identify the five basic factors you should consider throughout your quarry development planning.
   a. ____________________
   b. ____________________
   c. ____________________
   d. ____________________
   e. ____________________

3. What minimum length of access road should you provide to allow dump truck access to the top or a bench 30 feet above your quarry floor
   ____

4. What do you call the area where overburden is disposed?
   ____

5. Drilling has been difficult in your quarry site. Rockslides have made work hazardous. You have a choice of a 12-foot or a 20-foot bench height. Which would you choose under these circumstances?

____

6. Where should you locate the rock crushing, screening, and washing plant for your quarry?

____
____

7. Why should you set up a rock crushing plant on multiple levels whenever practical?

____
____
____

8. You should make plans to assure that all rock processing units operate at full capacity, continuously despite interruptions in material flow. What can you do to fulfill these operational requirements? ______________________________

____
____
____

9. Aggregates must often be washed free of fines, organic material, or other impurities. What provisions should you make for handling wash water where available water supplies are limited?

____
____
____

10. You expect a problem with oversize material. How can you prevent this material from being input to your rock crushing plant? ______________________

____

11. You have cleared and grubbed the quarry site to remove timber and brush. You should remove, or strip, the overburden next. How much overburden should you remove? __________

____

12. What two types of initial cuts would you use to establish the initial, vertical quarry face?
    a. ___________________
    b. ___________________

13. Occasionally a quarry face must be operated with rock layer or fracture surfaces inclined either into or away from the face. In such cases, is it easier to maintain a vertical face when the features dip toward or away from the face? Explain your answer. __________________________
    ____
    ____
    ____

Lesson 2
ANSWER SHEET FOR PRACTICE EXERCISE

	Learning Event
1. a. The *site layout plan* establishes the location and arrangement of the quarry and its supporting facilities. b. The *operations plan* specifies the methods and procedures to be used in developing and operating the complex.	Lesson Description
2. a. your mission d. economy of resources b. site conditions e. ease of operation c. safety	1
3. 300 feet $\frac{30 \text{ feet}}{0.10 \text{ grade}} = 300 \text{ feet}$ Haul and access road should not normally have grades steeper than 10 percent for dump truck operation. Thus, for a rise of 30 meters, you should allow at least 300 meters of uniformly-sloped access road.	2
4. a spoil area	2
5. 12-foot bench height; lower benches are preferred when drilling is difficult and where rockfall and rockslide hazards exist.	2
6. Basically, the rock crushing, screening, and washing plant should be located as close to the quarry face as possible without becoming endangered by blasting operations.	2
7. Rock crushing plants should be set up on multiple levels whenever possible to permit the use of gravity as an aid in moving materials to and through the plant using gravity chutes, ramps, bins, and similar devices.	
8. You should plan to have surge piles of material at each step in the rock processing operation.	2

		Learning Event
9.	If available water supplies are limited (or if environmental impact is important) a recirculating water system should be constructed using two ponds. One serves as a reservoir for clean water and one as a settlement pond where dirt, fines, and organic materials can be removed from the used wash water before it is allowed to return to the reservoir for reuse.	2
10.	You should install a grizzly to pre-screen the material and remove oversize rock. (It is preferable to install the grizzly in the quarry, but it can also be built over the plant's apron feeder.)	2
11.	Remove enough overburden to ascertain the structure and configuration of the underlying rock. All overburden need not be removed at once. Overburden removal should keep pace on a day-to-day basis once excavation begins.	6
12.	a. toe cuts b. ramp cuts	7
13.	Normally, it is easier to maintain a vertical face when rock layers slope away from the quarry face than it is if they slope toward the face. This is because rockslides are more likely where fractures or rock layers slope toward the excavation.	7